PART VII
Causality and mechanisms

·36·

The idea of mechanism

Stathis Psillos

Abstract

In this chapter, I disentangle two ideas of mechanism and point to the key problems they face. Section 36.2 offers an outline of the mechanical conception of mechanism, as this was introduced in the seventeenth century and developed later on. Section 36.3 presents Poincaré's critique of mechanical mechanism in relation with the principle of conservation of energy. The gist of this critique is that mechanical mechanisms are too easy to get to be informative, provided that energy is conserved. Section 36.4 motivates the quasi-mechanical conception of mechanism and traces it to Kant's *Critique of Judgement* and to C.D. Broad's critique of pure mechanism. Section 36.5 reconstructs Hegel's critique of the idea of quasi-mechanism, as this was developed in his *Science of Logic*. Hegel's problem, in essence, was that the unity that mechanisms possess is external to them and that the very idea that *all* explanation is mechanical is devoid of content. Section 36.6 brings together Poincaré's problem and Hegel's problem and concludes that though mechanisms are not the building blocks of nature, the search for mechanism is epistemologically and methodologically welcome.

36.1 Introduction

When we think about mechanisms, there are two general issues we need to consider. The first is broadly epistemic and has to do with the understanding of nature that identifying and knowing mechanisms yields. The second is broadly metaphysical and has to do with the status of mechanisms as building blocks of nature (and in particular, as fundamental constituents of causation). These two issues can be brought together under a certain assumption, which has had long historical pedigree, namely that nature is fundamentally mechanical.

What exactly does it mean to say that nature is *mechanical*? What is the content of this thesis? This assumption has had no concrete ahistorical conceptual content. Rather, its content has varied according to the dominant conception of nature that has characterized each epoch. Nor has it been the case that the very idea of mechanism has had a fixed and definite content. Even if in the seventeenth century and beyond, the idea of mechanism had something to do with matter in motion subject to mechanical laws, *current* conceptions of mechanism have only a very loose connection with this. A mechanism, nowadays, is virtually *any* relatively stable arrangement of entities such that, by engaging in certain interactions, a function is performed or an effect is brought about. To call a structure a mechanism is simply to *describe* it in a certain way – focusing on the steps or processes through which an effect is brought about.

This broad understanding of mechanism is typical of the new mechanical philosophy, as it is sometimes called, that has started to become a vocal, if not the dominant, approach to causation and explanation.[1] Take a very typical characterization of mechanism by Bechtel and Abrahamsen (2005, p. 423):

> (M) A mechanism is a structure performing a function in virtue of its component parts, component operations, and their organization. The orchestrated functioning of the mechanism is responsible for one or more phenomena.

On this conception,[2] a mechanism is *any* structure which is identified as such (that is as possessing a certain causal unity) via the function it performs. Moreover, a mechanism is a *complex* entity whose behaviour (that is, the function it performs) is determined by the properties, relations and interactions of its parts. This priority of the parts over the whole – and in particular, the view that the behaviour of the whole is determined by the behaviour of its parts – is the distinctive feature of this broad account of mechanism.

It will be helpful and accurate to distinguish between two concepts of mechanism – or, if you like, between two ideas of mechanism. We may call the first *mechanical* mechanism and the second *quasi-mechanical* mechanism. The first conception of mechanism is narrow: mechanisms are configurations of matter in motion subject to mechanical laws (*the laws of mechanics*). It is this conception that has been associated with the rise and dominance of the mechanical conception of nature in the seventeenth century. The key features of this conception are nicely captured by Margaret Wilson (1999, p. xiii, note 1):

> The mechanism characteristic of the new science of the seventeenth century may be briefly characterised as follows: Mechanists held that all macroscopic bodily phenomena result from the motions and impacts of submicroscopic particles, or corpuscles, each of which can be fully characterised in terms of a strictly limited range of (primary) properties: size, shape, motion and, perhaps, solidity and impenetrability.

As already noted, the second conception of mechanism is broader. A quasi-mechanical mechanism is *any* arrangement of parts into wholes in such a

[1] For defences of mechanical approaches to causation and explanation see Machamer Darden and Craver (2000), Glennan (2002; 2008) and Craver (2007). Craver and Dardon (2005) offer a nice summary/survey of recent conceptions of mechanism. For a critique of the mechanistic perspective, see Psillos (2004).

[2] For similar accounts of mechanism, see Machamer *et al.* (2000).

way that the behaviour of the whole depends on the properties of the parts and their mutual interactions. Rom Harré (1972, p. 116) has called this kind of mechanism *generative* mechanism. The focus is not on the mechanical properties of the parts, nor on the mechanical principles that govern the behaviour of the parts and determine the behaviour of the whole. Instead, the focus is on the causal relations there are between the parts and the whole. Generative mechanisms are taken to be the bearers of causal connections.[3] It is in virtue of them that the causes are supposed to produce the effects. There is a concomitant conception of mechanical explanation as a kind of decompositional explanation: an explanation of a whole in terms of its parts, their properties and their interactions. This second conception is, arguably, associated with Kant's idea of mechanism in his third critique.

In this chapter, I will disentangle these two ideas of mechanism and point to the key problems they face. Section 36.2 will offer an outline of the mechanical conception of mechanism, as this was introduced in the seventeenth century and developed later on. Section 36.3 will present Poincaré's critique of mechanical mechanism in relation with the principle of conservation of energy. The gist of this critique is that mechanical mechanisms are too easy to get to be informative, provided that energy is conserved. Section 36.4 will motivate the quasi-mechanical conception of mechanism and will trace it to Kant's *Critique of Judgement* and to C.D. Broad's critique of pure mechanism. Section 36.5 will reconstruct Hegel's critique of the idea of quasi-mechanism, as this was developed mainly in his *Science of Logic*. Hegel's problem, in essence, was that the unity that mechanisms possess is external to them and that the very idea that *all* explanation is mechanical is devoid of content. Section 36.6 will bring together Poincaré's problem and Hegel's problem and conclude that though mechanisms are not the building blocks of nature, the search for mechanism is epistemologically and methodologically welcome.

36.2 Mechanical mechanism

In the seventeenth century, the mechanical conception of nature was taken to be a weapon against the Aristotelian view that each and every explanation was not complete unless some efficient *and* some final cause were cited. The emergent mechanical philosophy placed in centre-stage the new science of mechanics and left Aristotelian physics behind. Accordingly, the call for a mechanical explanation of phenomena has had definite content: all natural phenomena are *produced* by the mechanical interactions of the parts of matter according to mechanical laws.

The broad contours of the mechanical conception of nature were not under much dispute, at least among those who identified themselves as mechanical

[3] As (Harré 1972, p. 118) has put it: 'not all mechanisms are mechanical'.

978–0–19–957413–1 36-Mckay-Illari-c36-drv Mckay (Typeset by SPi, Chennai) 774 of 928 October 30, 2010 12:55

OUP UNCORRECTED PROOF – FIRST PROOF, 30/10/2010, SPi

philosophers. The key ideas were that all natural phenomena are explicable mechanically in terms of matter in motion; that efficient causation should be understood, ultimately, in terms of *pushings* and *pullings*; and that final causation should be excised from nature.[4] Though definite, this conception was far from monolithic. As Marie Boas (1952) has explained in detail, there had been different and opposing conceptions as to the structure of matter (atomistic vs corpuscularian); the reality of the void (affirmation of the existence of empty space vs the plenum); the primary qualities of matter (solely extension vs richer conceptions that include solidity, impenetrability and other properties). And yet, the unifying idea was that all explanation is mechanical explanation and proceeds in terms of matter and motion. As Robert Boyle put it, matter and motion are 'the two grand and most catholick principles of bodies' (quoted by Boas, p. 468).

Part of the appeal of the mechanical conception of nature was that it stood against a rival framework for the explanation of natural phenomena and fared better than it. For Boyle, for instance, at stake were not the details of what he called the *mechanical hypothesis*, but its being superior to its Aristotelian rival. This was judged by Boyle to be the case on the basis of the fact that the mechanical hypothesis possessed virtues such as consistency, simplicity, comprehensiveness and applicability to the phenomena that outrun its rival.

With Newton, the content of the mechanical conception of nature was altered and broadened.[5] The category of *force* was firmly introduced alongside the traditional mechanical categories of *matter* in motion. Actually, though this category was not strictly speaking new, it was for the first time set in a mechanical framework in which it was measured by the *change* in the quantity of motion it could generate. But Newton insisted that his concept of force was mathematical (cf. *Principia*, Book I, Definition VIII). Mechanical interactions were enriched to include attractive and repulsive forces between particles. Mechanical explanation was taken to consist in the subsumption of phenomena under Newton's laws.

Capitalizing on Gregor Schiemann's enlightening (2008), it can be argued that even within what I have called the mechanical conception of mechanism, there have been two distinct senses of mechanism, one wide and another narrow. The wide sense takes it that matter in motion is the ultimate cause of all natural phenomena. As such, mechanism covers everything, but its content

[4] To be sure, most mechanical philosophers did find a role for final causation via God's design of the world, but crucially, this design was precisely that of a *mechanism*. More specifically, mechanical philosophers denied the presence in nature of immanent final causes such as Aristotelian forms. Indeed, an important characteristic of the mechanical conception of nature was its denial of *forms* as part of the acceptable ontology.

[5] Not necessarily to the eyes of his contemporaries. To some (e.g. Leibniz) Newton had just abandoned the principles of mechanical philosophy, especially in light of the admission of action at a distance.

is quite unspecific, since there is no commitment to specific laws or principles that govern the workings of the mechanism. The narrow sense of mechanism, on the other hand, has it that mechanisms are governed by the *laws of mechanics*, as enunciated paradigmatically by Newton and Lagrange. Mechanics becomes privileged because it offers universal structural principles. But then, the form of the mechanical conception of nature depends on the details of the principles of mechanics and the content of the concept of mechanical mechanism is specified by the historical development of mechanics.

Schiemann draws an important distinction between monistic and dualistic conceptions of mechanics and, consequently, of mechanisms. On the monistic conception, there is only one fundamental mechanical category; on the dualistic conception, there are two fundamental categories. The monistic conception is further divided into two sub-categories: one takes matter to be the fundamental mechanical concept (called materialist, by Schiemann) while the other takes force to be the single fundamental mechanical category (called dynamic, by Schiemann). Huygens and Descartes had materialist conceptions of mechanical mechanism, while Leibniz and Kant had dynamic conceptions. The dualist conception of mechanical mechanism admits two distinct fundamental mechanical concepts – matter *and* force. Newton was a dualist in this sense and so was Helmholtz, according to Schiemann. Helmholtz's case is particularly instructive since he proved the principle of conservation of energy. It is precisely this principle that, as we shall see in the next section, holds the key to the very possibility of a mechanical explanation of all phenomena.[6]

With the emergence of systematic theories of heat, electricity and magnetism, one of the central theoretical questions was how these were related to the theories of mechanics. In particular, did thermal, electrical and magnetic phenomena admit of mechanical explanations?

This question was addressed in two different ways. One, developed mostly in Britain, was by means of building of mechanical *models*. These models were meant to show (a) the realizability of the system under study (e.g. the electromagnetic field) by a mechanical system; and (b) the possible inner structure and mechanisms by means of which the physical system under study operates. The other way was developed mostly on continental Europe and was the construction of abstract mechanical *theories* under which the phenomena under study were subsumed and explained. These theories were mechanical because they started with principles that embodied laws of mechanics and offered explanation by deductive subsumption. This tradition scorned the construction of mechanical models (especially of the wheels-and-pulleys form

[6] As Schiemann (2008, p. 90) notes, what made the principle of conservation of energy special, at least for Helmholtz, was that energy can 'be used directly for measuring things (particularly mechanical work and heat) and their conserving properties can be examined experimentally in physical processes'.

that many British scientists of the time were fond of). But even within this model-building tradition, especially in its mature post-Maxwellian period, mechanical models were taken to be, by and large, heuristic and illustrative devices – the focus being on the development of systematic theories (mostly based on abstract theoretical principles such as those of Lagrangian dynamics) under which the phenomena under study were subsumed and explained. Joseph Larmor (1894, p. 417) drew this division of labour clearly when he noticed

> (t)he division of the problem of the determination of the constitution of a partly concealed dynamical system, such as the aether, into two independent parts. The first part is the determination of some form of energy-function which will explain the recognised dynamical properties of the system, and which may be further tested by its application to the discovery of new properties. The second part is the building up in actuality or in imagination of some mechanical system which will serve as a model or illustration of a medium possessing such an energy function.

36.3 Poincaré's problem

How exactly was the idea of a mechanical explanation to be rendered? The problem here was not so much related to the nature of explanation as to what principles count as *mechanical*. In 1900, Henri Poincaré addressed the International Congress of Physics in Paris with the paper 'Relations entre la Physique Expérimentale et de la Physique Mathématique' (cf. 1900; this paper was reproduced as chapters 9 and 10 of his 1902). He did acknowledge that most theorists had a constant predilection for explanations borrowed from mechanics. Historically, these attempts had taken two particular forms: either they traced all phenomena back to the motion of molecules acting-at-a-distance in accordance to central force-laws; or, they suppressed central forces and traced all phenomena back to the contiguous actions of molecules that depart from the rectilinear path only by collisions. 'In a word' Poincaré said, 'they all [physicists] wish to bend nature into a certain form, and unless they can do this they cannot be satisfied'. (*ibid.*) And he immediately queried: 'Is nature flexible enough for this?'

The answer is positive, but in a surprising way. Poincaré's ground-breaking contribution to this issue was the proof of a theorem that a necessary and sufficient condition for a complete mechanical explanation of a set of phenomena is that there are suitable experimental quantities that can be identified as the kinetic and the potential energy such that they satisfy the principle of conservation of energy.[7] Given that such energy functions can be specified,

[7] The details of the proof (as well as further discussion of Poincaré's conception of mechanical explanation) are given in my (1995).

Poincaré proved that there will be *some* configuration of matter in motion (that is, a configuration of particles with certain positions and momenta) that can underpin (or model) a set of phenomena. As he put it:

> In order to demonstrate the possibility of a mechanical explanation of electricity, we do not have to preoccupy ourselves with finding this explanation itself; it is sufficient to know the expressions of the two functions T and U which are the two parts of energy, to form with these two functions the equations of Lagrange and, afterwards, to compare these equations with the experimental laws (1890/1901, p. viii).

Poincaré presented these results in a series of lectures on light and electromagnetism – delivered at the Sorbonne in 1888 and published as *Électricité et Optique* in 1890 – which primarily aimed to deliver Maxwell's promise, i.e. to show that electromagnetic phenomena could be subsumed under, and represented in, a suitable mechanical framework. As Poincaré put it, he aimed to show that 'Maxwell does not give a mechanical explanation of electricity and magnetism; he confines himself to showing that such an explanation is possible' (1890/1901, p. iv). In effect, Poincaré noted that once the first part of Larmor's foregoing division of labour is dealt with, the second part (the construction of configurations of matter in motion) takes care of itself. Maxwell's achievement, according to Poincaré, was precisely this and he 'was then certain of a mechanical explanation of electricity' (1902, p. 224).

The irony was that Poincaré's demonstration had the following important corollary: if there is one mechanical explanation of a set of phenomena, i.e. if there is a possible configuration of matter in motion that can underpin a set of phenomena, there is an *infinity* of them. And not just that. Another theorem proved by the French mathematician Gabriel Königs suggested that for any material system such that the motions of a set of masses (or material molecules) is described by a system of linear differential equations of the generalized coordinates of these masses, these differential equations (which are normally attributed to the existence of forces between the masses) would be satisfied even if one replaced all forces by a suitably chosen system of *rigid connections* between these masses. Indeed, Heinrich Hertz (1894) had made use of this result to develop a system of mechanics that did away with forces altogether.

Poincaré thought that these formal results concerning the multiplicity of mechanical configurations that could underpin a set of phenomena described by a set of differential equations were natural. They were only the mathematical counterpart of the well-known historical fact that in attempting to form potential mechanical explanations of natural phenomena, scientists had chosen several theoretical hypotheses, e.g. forces acting-at-a-distance, retarded potentials, continuous or molecular media, hypothetical fluids, etc. Poincaré was sensitive to the view that even though some of these attempts had been discredited in favour of others, more than one potential mechanical model of, say, electromagnetic phenomena were still available (cf. 1900, pp. 1166–1167).[8]

So, the search for a *complete* mechanical explanation of electromagnetic phenomena was heavily underdetermined by possible configurations of matter in motion. Different underlying mechanisms could all be taken to give rise to the laws of electromagnetic phenomena. By the same token, though the possibility of a mechanical explanation of electromagnetic phenomena is secured, the empirical facts alone could not dictate any choice between different mechanical configurations that satisfy the same differential equations of motion. The choice among competing underlying mechanisms (possible configurations of matter in motion) was heavily underdetermined by the empirical facts. How then can one choose between these possible mechanical configurations? How can one find the correct complete mechanical explanation of electromagnetic phenomena? For Poincaré this was a misguided question. As he said 'The day will perhaps come when physicists will no longer concern themselves with questions which are inaccessible to positive methods and will leave them to the metaphysicians' (1902, p. 225). His advice to his fellow scientists was to content themselves with the possibility of a mechanical explanation of all conservative phenomena and to abandon hope of finding the true mechanical configuration that underlies a particular set of phenomena. He (1900, p. 1173) stressed:

> We ought therefore to set limits to our ambition. Let us not seek to formulate a mechanical explanation; let us be content to show that we can always find one if we wish. In this we have succeeded.

According to Poincaré, the search for mechanical explanation (i.e. for a configuration of matter in motion) of a set of phenomena is of little value not just because this search is massively underdetermined by the phenomena under study but mainly because this search sets the wrong target. What matters, for Poincaré, is not the search of mechanism *per se*, but rather the search for *unity* of the phenomena under laws of conservation. Understanding is promoted by the unification of the phenomena and not by finding mechanical mechanisms

[8] The turning point in Poincaré's thinking about mechanics is in his review of Hertzs's (1894) for *Revue Générale des Sciences*. Concerning the 'classical system', which rests on Newton's laws, Poincaré agreed with Hertz that it ought to be abandoned as a foundation for mechanics (cf. 1897, p. 239). Part of the problem was that there were no adequate definitions of force and mass. But another part was that Newton's system was incomplete precisely because it passed over in silence the principle of conservation of energy (cf. 1897, p. 237). Like Hertz, Poincaré was more sympathetic to the 'energetic system', which was based on the principle of conservation of energy and Hamilton's principle that regulates the temporal evolution of a system (cf. 1897, pp. 239–240). According to Poincaré (1897, pp. 240–241) the basic advantage of the energetic system was that in a number of well-defined cases, the principle of conservation of energy and the subsequent Lagrangian equations of motion could give a full description of the laws of motion of a system.

that bring them about. As he said 'The end we seek (. . .) is not the mechanism. The true and only aim is unity'. (*ibid.*).

One may question the status of the law of conservation of energy as a mechanical principle. But that's beside the point. For the point is precisely that there is no fixed characterization of what counts as mechanical. It may well be that Poincaré's notion of mechanical explanation is too wide from the point of view of physical theory, since it hardly excludes any phenomena from being subject to mechanical explanation. Still, and this is quite important, it does block certain versions of vitalism that stipulate new kinds of forces. As is well known, in the twentieth century, the search for mechanisms and mechanical explanations was taken to be a weapon against vitalism. One key problem with vitalist explanations (at least of the sort that C.D. Broad has dubbed *substantial vitalism*) is that they are in conflict with the principle of conservation of energy and in *this* sense, they cannot be cast, even in principle, as mechanical explanations.

The significance of Poincaré's problem for the mechanical conception of mechanism can hardly be overestimated. But we should be careful to note exactly what this problem is. It is not that mechanical mechanisms are unavailable or non-existent. It is not that nature is *not* mechanical. Hence, it is not that mechanical explanation – that is, explanation in terms of mechanical mechanisms – is impossible. On the contrary, Poincaré has secured its very possibility, thereby securing, as it were, the victory of traditional mechanical philosophy over Aristotelianism. Rather, the problem for the mechanical conception of mechanism that Poincaré has identified is that, mechanical mechanisms are *too* easy to get, provided nature is conservative. Under certain plausible assumptions that involve the principle of conservation of energy, the call for mechanical explanation is so readily satisfiable that it ceases to be genuinely informative.

36.4 Quasi-mechanical mechanisms

In his (1969, p. 216), A.C. Ewing drew a distinction between two conceptions of mechanical necessity in Kant's *Third Critique*. The first is related to what I have called the mechanical conception of mechanism: a determination of the properties of a whole by reference to matter in motion, and in particular by the mechanical properties of its parts and the mechanical laws they obey. The second, which Ewing calls 'quasi-mechanical', is still a determination of the properties of the whole by reference to the properties of its parts, but with no particular reference to mechanical properties and laws. This quasi-mechanical conception of mechanism is broader than the mechanical conception since there is no demand that the laws that govern the behaviour of the parts, or the properties of these parts, are mechanical – at least in the strict sense associated with the mechanical conception.

Peter McLaughlin (1990) has developed a similar account Kant's conception of mechanical explanation, according to which the mechanism of nature is a form of causation, whose differentia is that it takes it that the whole is determined by its parts. Thus understood, a mechanical explanation is a kind of de-compositional explanation: an explanation of a whole in terms of its parts, their properties and their interactions. McLaughlin bases his account on the following point made by Kant in his *Critique of Judgement* (1790/2008, p. 408):

> Now where we consider a material whole, and regard it as in point of form a product resulting from the parts and their powers and capacities of self-integration (including as parts any foreign material introduced by the co-operative action of the original parts), what we represent to ourselves in this way is a mechanical generation of the whole.

Accordingly, what renders a structure a mechanism is the fact that it possesses a reductive unity: its behaviour is determined by the properties its part have 'on their own, that is independently of the whole' (McLaughlin 1990, p. 153).

This is not the place to discuss in any detail whether this was indeed Kant's own conception.[9] The key point is that if this conception is viable at all (and, as the current mechanistic turn demonstrates, it is), then the concept of mechanism is not tied to mechanics; nor to the operation of specifically mechanical laws; nor to the ultimate determination of the behaviour of mechanism by reference to mechanical properties and interactions. Rather, the mechanism is *any* complex entity which exhibits reductive stability and unity in the sense that its behaviour is determined by the behaviour of its parts.

Kant, to be sure, contrasted mechanical explanation to teleological explanation. In its famous antinomy of the teleological power of judgement, he contrasted organisms to mechanisms. *Qua* material things, organisms (like all material things) should be generated and governed by merely mechanical laws. And yet, some material things (*qua* organisms, and hence natural purposes, as Kant put it) 'cannot be judged as possible according to merely mechanical laws (judging them requires an entirely different law of causality, namely that of final causes)'. The defining characteristics of an organism – that is of a non-mechanism – are two: (a) the whole precedes its parts and, ultimately, determines them; and (b) the parts are in reciprocal relations of cause and effect. Famously, Kant claimed that the very idea of non-mechanism (organism) is regulative and not constitutive – we have the right to proceed *as if* there were organisms (non-mechanisms) but this is not something that can

[9] There are competing views on this. Hannah Ginsborg takes it that Kant's conception of mechanism is closely tied to his account of forces and mechanical laws. For her, according to Kant, 'we explain something mechanically when we explain its production as a result of the unaided powers of matter as such' (2004, p. 42). For an attempted synthesis of Ginsborg's and McLaughlin's views, see Breitenbach (2006).

be known or proved, though Kant did think that this regulative principle is a *safe* presupposition, not liable to refutation by the progress of science.

This contrast of mechanism and non-mechanism suggests that the key feature of mechanism – what really sets it apart from organism – is the priority of the parts over the whole in the constitution of the mechanism and the determination of its behaviour.[10] It is also worth noting that it is precisely this contrast that C.D. Broad (1925) has had in mind in his own critique of mechanism.

Broad mounted an attack on what he called 'the ideal of Pure Mechanism'. This is an extreme and purified version of what I have called the mechanical conception of mechanism. Broad's Pure Mechanism is a worldview, which he (1925, p. 45) characterizes thus:

> The essence of Pure Mechanism is
>
> (a) a single kind of stuff, all of whose parts are exactly alike except for differences of position and motion;
>
> (b) a single fundamental kind of change, viz., change of position (. . .);
>
> (c) a single elementary causal law, according to which particles influence each other by pairs; and
>
> (d) a single and simple principle of composition, according to which the behaviour of any aggregate of particles, or the influence of any one aggregate on any other, follows in a uniform way from the mutual influences of the constituent particles taken by pairs.

The gist of Pure Mechanism is that it is an ontically reductive thesis and in particular a reductive thesis with a very austere reductive basis of a single kind of fundamental particle, a single kind of change and a single causal law governing the interaction of the fundamental particles. Broad contrasted this view with two others. The first is what he called emergent vitalism. This is the view that living organisms and their behaviour cannot be fully and exhaustively determined by the properties and behaviour of their component parts, as these would be captured by the ideal of Pure Mechanism. Emergent vitalism is also opposed to a view we have already noted in Section 36.3, viz.,

[10] In her (2004), Ginsborg takes it that *qua* natural purposes, organisms are non-machine-like (and hence mechanically inexplicable) in the sense that 'they are not assemblages of independent parts, but that they are instead composed of parts which depend for their existence on one another, so that the organism as a whole both produces and is produced by its own parts, and is thus in Kant's words 'cause and effect of itself'' (2004, p. 46). This way to read Kant's account of organism distinguishes it from mechanism in two senses. (a) Organism cannot be explained in terms of the powers of matter as such; and (b) organism is such that its parts depend on the whole and cannot 'exist independently of the whole to which they belong' (2004, p. 47). Hence, what renders mechanism distinctive is precisely the fact that its unity and behaviour is determined by its parts, as they are independently of their presence in the whole. For a useful attempt to synthesise Kant's antinomy in the light of modern evolutionary biology, see Walsh (2006).

substantial vitalism: that living organisms are set apart from mechanism by an extra element (a kind of life-conferring force) that they share while pure mechanisms do not. In denying substantial vitalism, emergent vitalism puts emphasis on the structural arrangement of the whole vis-à-vis its parts and on the interaction among the parts when they are put together in a whole. A certain whole W may consist of constituents A, B, C placed in a certain relation R(A, B, C). There is emergence – emergent properties – when A, B, C cannot determine, even in principle, the properties of R(A, B, C).

Broad (1925, p. 61) put this point in terms of the lack of an in principle deducibility of the properties of R(A, B, C) 'from the most complete knowledge of the properties of A, B, and C in isolation or in other wholes which are not of the form R(A, B, C)'. This way to put the matter might be unfortunate, since what really matters is the metaphysical determination (or its lack thereof) of the whole by its parts and not deducibility *per se* – which is dependent on the epistemic situation we might happen to be in. But what matters for our purposes is Broad's thought that the denial of Pure Mechanism need not lead to the admission of spooky forces and mysterious powers, associated with substantial vitalism.

Still, our main concern here is not the opposition of Pure Mechanism to emergent vitalism, but rather its opposition to what Broad rightly took it to be a milder form of mechanism. This form, which Broad associated with what he called *Biological Mechanism*, is committed to the view that the behaviour of a whole (and of a living body in particular) is determined by its constituents, their properties and the laws they obey, but relies on a broader conception of what counts as a constituent and what laws are admissible. As Broad (1925, p. 46) put it:

> Probably all that he [a biologist who calls himself a 'Mechanist'] wishes to assert is that a living body is composed only of constituents which do or might occur in non-living bodies, and that its characteristic behaviour is wholly deducible from its structure and components and from the chemical, physical and dynamical laws which these materials would obey if they were isolated or were in non-living combinations. Whether the apparently different kinds of chemical substance are really just so many different configurations of a single kind of particles, and whether the chemical and physical laws are just the compounded results of the action of a number of similar particles obeying a single elementary law and a single principle of composition, he is not compelled as a biologist to decide.

This is, clearly, what we have called a quasi-mechanical conception of mechanism, and as Broad rightly notes, this kind of conception is enough to set the mechanist biologist apart from the emergent vitalist. The controversy need not be put, nor is it useful to be put, in terms of the ideal of Pure Mechanism.[11]

[11] In his very useful (2005), Garland Allen notes that 'operative, or explanatory mechanism refers to a step-by-step description or explanation of how components in a system interact to yield

Enough has been said, I hope, to persuade the reader that there is a distinct quasi-mechanical idea of mechanism, which – to recapitulate – proclaims a form of determination of a whole by its parts, their properties and interactions, as these would occur independently of their presence in the whole. With this is mind, let us now see what the key problem of this quasi-mechanical conception of mechanism is.

36.5 Hegel's problem

Long before Poincaré's critique of mechanical mechanism, Georg Hegel had, in his *Science of Logic*, attacked the idea that all explanation must be mechanical. According to James Kreines (2004), Hegel argued that making mechanism an absolute category – applicable to everything – obscures the distinction between explanation and description and hence undermines itself.

Hegel's writings on mechanism are rather cryptic (and perhaps, obscure). Essentially, he took the characteristic of mechanism to be that it possesses only an external unity. Its constituents (the objects that constitute it) retain their independence and self-determination, although they are parts of the mechanism. As he put it in his *The Encyclopaedia Logic* (1832/1991, p. 278) 'the relation of mechanical objects to one another is, to start with, only an external one, a relation in which the objects that are related to one another retain the semblance of independence'. And in his *Science of Logic* (2002, 711) he stressed:

> This is what constitutes the character of *mechanism,* namely, that whatever relation obtains between the things combined, this relation is one *extraneous* to them that does not concern their nature at all, and even if it is accompanied by a semblance of unity it remains nothing more *than composition, mixture, aggregation* and the like.

The determinant of the unity of a mechanism, or as Hegel put it 'the *form* that constitutes [its] difference and combines [it] into a unity' is 'an external, indifferent one; whether it be a *mixture,* or again an *order,* a certain *arrangement* of parts and sides, all these are combinations that are indifferent to what is so related' (2002, p. 713). And elsewhere, he stressed that being external, the unity of the mechanism 'is essentially one in which no *self-determination* is manifested' (2002, p. 734).

On Kreines's reading of Hegel's critique of mechanism, Hegel raised a perfectly sensible and quite forceful objection to the view that *all* explanation

a particular outcome (...)' (cf. 2005, p. 261). He contrasts this with what he calls 'philosophical mechanism' which he takes it to assert that living things are material entities. He then offers an instructive historical account of approaches to biological mechanism in the early twentieth century (and their opposition to vitalism), emphasising that 'the form that Mechanistic thinking took in the early twentieth century (...) differed from earlier (eighteenth and nineteenth-century) mechanistic traditions. It was physico-chemical not merely mechanical (...)' (2005, p. 280).

is mechanical explanation; that the only mode of explanation is mechanical; that to explain X is to offer a mechanical explanation of it.

Hegel's argument against the idea of mechanism – *qua* an all-encompassing explanatory concept – goes like this. Mechanistic explanation proceeds in terms of breaking an object down to its parts and of showing its dependence on them and their properties and relations. Explanation, then, amounts to a certain de-composition of the explanandum, viz., of a composite object whose behaviour is the result of the properties of, and interactions among, its parts. But there are indefinitely many ways to decompose something to parts and to relate it and its behaviour to them. For the call for explanation to have any bite all, there must be some principled distinction between those de-compositions that are merely descriptions of the explanandum and those decompositions that are genuinely explanatory. In particular, some decomposition – that which offers the mechanical *explanation* – must be privileged over the others, which might well reflect only pragmatic criteria or subjective interests. But how is this distinction to be drawn within the view that all explanation is mechanical? If all explanation is indeed mechanical, and if mechanical explanation amounts to decomposition, no line can be drawn between explanation and description – no particular way to decompose the explanandum is privileged over the others by being mechanical; mechanical as opposed to what? All decompositions will be equally mechanical and equally arbitrary. Hence, there will be no difference between explanation and description.

Hegel was pushing this line of argument in order to promote his own organic view of nature and, in particular, to reinstate a teleological kind of explanation – one that explains the unity of a composite object in terms of its internal purposeful activity.[12] But the point he makes in very general. In essence, Hegel's problem is that something external to the mechanism (considered as an aggregate of parts) is necessary to understand how mechanistic explanation is possible. His general point is that the unity of a mechanism is not just of matter of arranging a set of elements into a whole; nor is it just a matter of listing their properties and mutual relations. Nor is it determined by the parts of the mechanism, as they are independently of their occurrence within the mechanism. There are indefinitely many ways arrange parts into wholes, or to decompose wholes into parts. Most of them will be arbitrary since they will *not* be explanatorily relevant. The unity of the mechanism comes from something external to it, viz., from its function – from what it is meant to be a mechanism *for*. The function that a mechanism performs is something external to the description of the mechanism. It is the function that fixes a criterion of explanatory relevance. Some descriptions of the mechanism

[12] For an informative and intelligible account of Hegel's organic world view, see Beiser (2005, chapter 4).

are explanatorily relevant while others are not because the former and not the latter explain how the mechanism performs a certain function.

Let me illustrate this point with a couple of examples. Consider a toilet flush – a very simple mechanism indeed. What confers unity to it *qua* mechanism is the function it performs. As a complex entity, it can be decomposed into elements in indefinitely many different ways. Actually, in all probability, there is a description of it in terms of the interactions of the atoms of water and their collisions with the walls of the tank, etc. What fixes the explanatorily relevant description is surely the function it performs. Or consider telephone conversation through which some information is passed over from one end to the other – a very simple social mechanism. What confers unity to it *qua* mechanism is its function, viz., to transfer information between two ends. In all probability, there is a description of this mechanism in terms of the interactions of sound waves, collisions of particles, triggering of nerve-endings, etc. But this description is explanatorily irrelevant when it comes to explaining how this simple social mechanism performs its function. Notice that a point brought out by these examples, and certainly a point that Hegel had in mind, is that the truth of a description (supposing that it is to be had) does not necessarily render this description explanatorily relevant.

We could sum up Hegel's problem like this: first the function, then the mechanism.[13] The functional unity of the mechanism determines, ultimately, which of the many properties that the constituents of the mechanism have are relevant to the explanation of the performance and function of the whole. Hegel (1832/1991, p. 275) did think that mechanism is a form of objectivity, claimed that it is applicable to areas other than 'the special physical department from which it derives its name' but denied that it is an 'absolute category' that is constitutive of 'rational cognition in general'.

36.6 Concluding thoughts

Qua thinkers, Hegel and Poincaré were as different as chalk and cheese. Yet, they both point – with different philosophical arguments – towards a decline of the mechanistic worldview. It's not that there are no mechanisms. Actually, mechanisms, in the broad sense of stable arrangements of matter in motion, are ubiquitous. But it does not follow from this that nature has a definite mechanical structure (or, if that's too strong, that we cannot know which definite mechanical structure is the one actually characterizing nature). This is, in essence, Poincaré's problem. How the mechanisms are individuated is a

[13] This is indeed something that many modern mechanists have come to accept – but it is certainly not universally acknowledged among the new mechanists.

matter external to them – what counts as a mechanism, where it starts and where it stops, what kind of parts are salient and what kind of properties are relevant depend on the function they are meant to perform. The unity of the mechanisms is not intrinsic but extrinsic to them. This is, in essence, Hegel's problem. But even after a function has been determined, there are indefinitely many ways to configure mechanical mechanisms that perform it; that is, to offer a mechanical model (a configuration of matter in motion) that performs it. This is a corollary of Poincaré's problem.[14] Nature, even if it is mechanical, does not fix the boundaries of mechanisms. When it comes to the search for mechanisms, *anything* can count as a quasi-mechanism provided it performs a function that it is meant to explain. This is a corollary of Hegel's problem.

So, are mechanisms the ultimate building blocks of nature? The answer is both positive and negative. It is positive, given that the world is governed by conservation laws. But it is negative, given that mechanisms are functionally individuated: there are many ways to skin the cat!

Does the search for mechanism improve understanding? The answer is unequivocally positive. The description of a mechanism is a theoretical description and, as such, it tells a story as to how the phenomenon under study is brought about – if the story is true, our understanding of nature is enhanced. Insofar as mechanisms are taken to be functionally individuated stable explanatory structures (whose exact content and scope may well vary with our best conception of the world) which enhance our understanding of how some effects are brought about or are the realizers of certain functions, they can play a useful role in the toolkit of explanation.

Acknowledgements

Many thanks to two anonymous readers for extremely useful and sensitive comments and to Phyllis McKay Illari, Federica Russo and Jon Williamson.

References

Allen, G. F. (2005) Mechanism, vitalism and organicism in late nineteenth and twentieth-century biology: The importance of historical context, *Studies in the History and Philosophy of Biological and Biomedical Sciences* **36**: 261–283.

[14] Hegel was confident that 'not even the phenomena and processes of the physical domain in the narrower sense of the word (such as the phenomena of light, heat, magnetism, and electricity, for instance) can be explained in a merely mechanical way (i.e. through pressure, collision, displacement of parts and the like' (1832/1991, p. 195). Poincaré proved him wrong on this.

Bechtel, W. & Abrahamsen, A. (2005) Explanation: A mechanist alternative, *Studies in the History and Philosophy of Biological and Biomedical Sciences* **36**: 421–441.

Beiser, F. (2005) *Hegel*, New York: Routledge.

Boas, M. (1952) The establishment of the mechanical philosophy, *Osiris* **10**: 412–541.

Breitenbach, A. (2006) Mechanical explanation of nature and its limits in Kant's *Critique of Judgement*, *Studies in the History and Philosophy of Biological and Biomedical Sciences* **37**: 694–711.

Broad, C. D. (1925) *Mind and its Place in Nature*, London: Routledge and Kegan Paul.

Craver, C. (2007) *Explaining the Brain: Mechanisms and the Mosaic Unity of Neuroscience*, New York: Oxford University Press.

Craver, C. & Darden, L. (2005) Introduction, *Studies Studies in the History and Philosophy of Biological and Biomedical Sciences* **36**: 233–244.

Ginsborg, H. (2004) Two kinds of mechanical inexplicability in Kant and Aristotle, *Journal of the History of Philosophy* **42**: 33–65.

Glennan, S. (2002) Rethinking mechanical explanation, *Philosophy of Science* **69**: S342–S353.

Glennan, S. (2008) Mechanisms in S. Psillos and M. Curd (eds) *The Routldege Companion to Philosophy of Science*, London: Routledge, pp. 376–384.

Harre, Rom (1972) *The Philosophies of Science: An Introductory Survey*, Oxford: Oxford University Press.

Hegel, G. W. F. (1832/1991) *The Encyclopaedia Logic, Part I of the Encyclopaedia of Philosophical Sciences with the Zusätze*, (T. F. Geraets, W. A. Suchting & H. S. Harris (trans.) Indianapolis & Cambridge: Hackett Publishing Company.

Hegel, G. W. F. (2002) *The Science of Logic*, London: Routledge.

Hertz, H. (1894) *The Principles of Mechanics Presented in a New Form*, (first English Trans. 1899, reprinted by Dover, 1955) New York: Dover Publications.

Ewing, A. C. (1969) *Kant's Treatment of Causality*, Hamden Conn.: Archon Books

Kant, I. (1790/2008) *Critique of Judgement*, N. Walker & J. C. Meredith (trans.), Oxford: Oxford University Press

Kreines, J. (2004) Hegel's critique of pure mechanism and the philosophical appeal of the logic project, *European Journal of Philosophy* **12**: 38–74.

Larmor, J. (1894) A dynamical theory of the electric and luminiferous medium (Part I), *Philosophical Transactions of the Royal Society* **185**: 719–822; reprinted in J. Larmor *Mathematical and Physical Papers*, Vol. 1, Cambridge: Cambridge University Press (1929).

Machamer, P. Darden, L. & Craver C. (2000) Thinking about mechanisms, *Philosophy of Science* **67**: 1–25.

McLaughlin, P. (1990) *Kant's Critique of Teleology in Biological Explanation*, Lewiston NY : Edwin Mellon Press.

Poincaré, H. (1890/1901) *Électricité et Optique: La Lumière et les Théories Électromagnétiques*, 2nd edition, Paris: Gathier-Villairs.

Poincaré, H. (1897) Les Idées de Hertz sur la Mécanique, *Revue Générale des Sciences* **8**: 734–743; reproduced in *Ouevres de Henri Poincaré*, VII, 231–250, (1952) Paris: Gauthier-Villars.

Poincaré, H. (1900) Relations entre la Physique Expérimentale et de la Physique Mathématique, *Revue Générale des Sciences* **11**: 1163–1165.

Poincaré, H. (1902) *La Science et L'Hypothése* (1968 reprint), Paris: Flammarion.

Psillos, S. (1995) Poincaré's conception of mechanical explanation, in J.-L. Greffe, G. Heinzmann & K. Lorenz (eds) *Henri Poincaré: Science and Philosophy*, Berlin: Academie Verlag & Paris: Albert Blanchard.

Schiemann, G. (2008) *Hermann von Helmholtz's Mechanism: The Loss of Certainty*, Berlin: Springer.

Walsh, D. M. (2006) Organisms as natural purposes: The contemporary evolutionary perspective, *Studies in the History and Philosophy of Biological and Biomedical Sciences* **37**: 771–791.

Wilson, M. (1999) *Ideas and Mechanism*, Princeton: Princeton University Press.